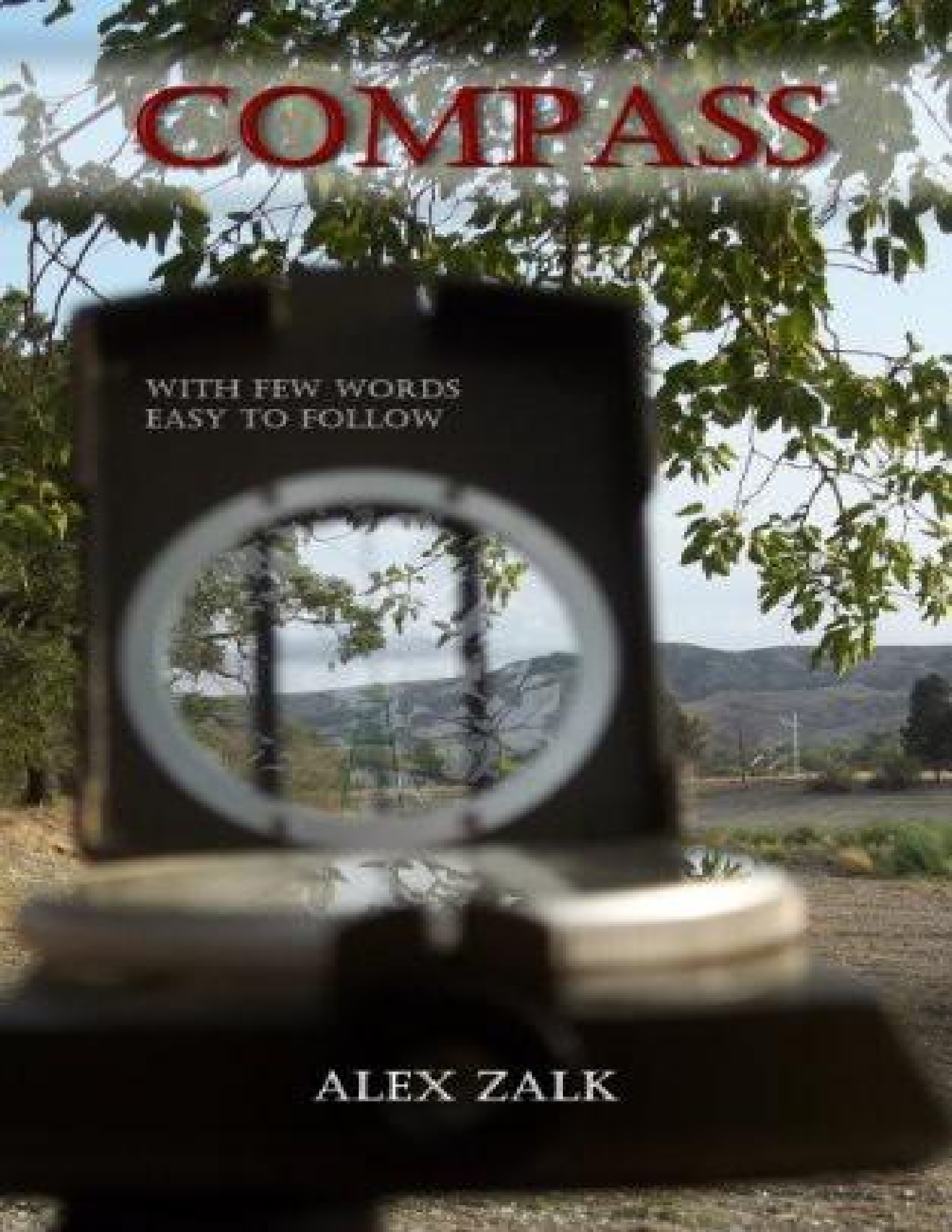
COMPASS



ALEX ZALK

Compass

Alex Zalk

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Forewords

A compass is extremely valuable equipment used by scouts and hikers, pilots and campers, in airplanes, captains of ships at sea, on spaceships and guided missiles, by car drivers and mountain climbers (even fortune tellers!). It’s everywhere. It is such a simple and powerful tool that everyone should know how to use it. Prepare yourself and you always find the way!

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The history

The magnetic compass is a very old invention and is widely believed that it is an old Chinese invention like gunpowder and paper to name few. It was probably first made in China during the Qin dynasty (221-206 B.C.). Chinese used it for fortune telling and used lodestones for their fortune telling boards. Lodestones are Magnetites, Ferrites or magnetic oxides and are natural magnets.

Eventually it was noticed that the lodestones could point real directions, leading to the first compass. The first pointing device was a spoon-shaped lodestone that would always point south (not north!).

As a result the device was adopted for navigation prior to which position, destination, and direction at sea were primarily determined by the sighting of landmarks, and observation of the position of celestial bodies. Astronomical knowledge was used to determine their proper heading, while the Vikings may have some birefringent crystals to determine the sun's direction and elevation from the polarization of daylight for cloudy days as well.

The compass

Types of Compasses

The compass, just the good old magnetic compass can be very different from model to model. You will here a lot of names. Some might be synonyms and some not. Here are few to name. Lensatic, protractor, wrist… Basic, advanced, accessory… Orienteering[1] compass, navigational[2] compass and so on. Let's make it clear.

1 A competitive sport in which participants find their way to various checkpoints across rough country with the aid of a map and compass.

2 The skill or process of plotting a route and directing along it. In other words, — the act of setting and holding a course or the guidance of ships or airplanes or else from place to place.

Accessory compasses are small compasses to have for backup reasons. They are small and usually attached to other things like knifes or bags. They are present in survival kits. Compasses on mobile phones, watches or other similar devices would count as accessory ones. They can not be primary ones as they lack dependability like good old magnetic compasses have. I can tell many reasons but I'll make it short. Out in wild it is very easy to fall in river or have rainy day. Electronic devices are not friendly to water not to mention battery issues.

Open face and **closed face** compass names are much self explanatory. Closed face ones designed after pocket watches possibly and sometimes are called as Hunter cased.

Prismatic compass must have prism for reading the scale when taking a bearing. K&R Meridian compasses are good examples.

Lensatic compass has lens for sighting. May also have other lens for reading. US Military compasses are good examples.

Transit compasses would have rear and front sights without optics.

And widespread **Baseplate Compass** mounted on a transparent baseplate as usual that could be used as *Protractor*.

Wrist compasses have wrist strap as expected.

You may here other names for compass by their function like: **Nautical compass**, **Aeronautical compass**, **marching compass**, **pocket compass**, **escape compass**, **Survey** and **artillery** and so on.

The **orienteering compass** as well called **mountaineering compass** is the usual magnetic type that has a needle that always points north and has a dial to be turned to find directions.

Orienteering is a competitive sport in which participants navigate unfamiliar territories using a map and compass to get from point to point. It is a timed, so speed and ease of use of compass are important. A **thumb compass** is an orienteering compass with special loop to fit the thumb, allowing compass to be ready to use. Its design allows holding a compass and a map in readable position in one hand.

Most people use a compass for fun, for instance with hiking or camping. In these cases basic compasses like the thumb compass or any orienteering compasses that can be read over a map are appropriate. When travel is over a short distance, basic markings for cardinal directions and a basic level of understanding compasses is needed. But where large distances are covered and a slight variation of degrees would offset your course, a deeper understanding of compass reading is required. Understanding declination between true north and magnetic north and course-of-direction arrow combined with advanced compass instructions requires more study and materials, that sure be covered in this book.

Digital and Modern Compasses

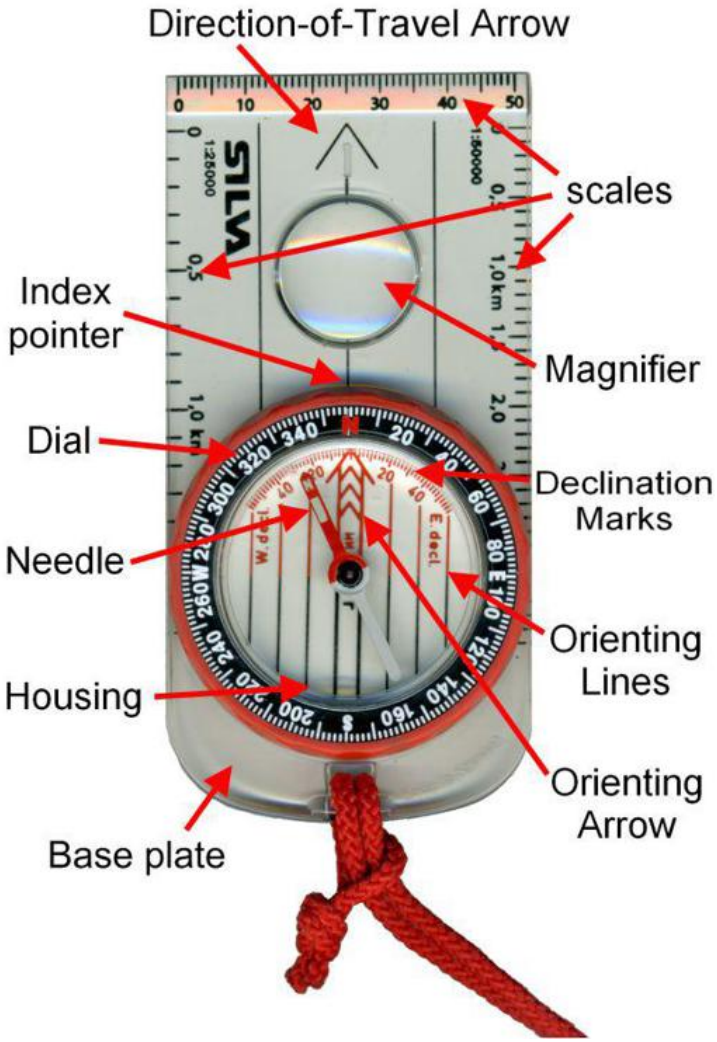
Digital compasses do the same thing as magnetic ones, they show directions. But they have digital display that make easier to read. On other hand they are battery powered, so energy dependable and often subject to calibration. Have backup batteries for digital compass if you ever plan to depend on them.

The Gyroscopic Compass

A **gyrocompass** is a non-magnetic compass which is based on a fast-spinning disc and rotation of the Earth to automatically find geographical direction. Gyroscopic compasses are aligned to the true North. They are often used by ships and aircraft so that local ferromagnetic metals and magnetic fields don’t interfere with navigation. Gyroscopic compasses are set to point true north using magnetic compass and then periodically checked with a magnetic compass to assure accuracy.

A **fibre optic gyroscope** (FOG) senses changes in orientation. Its principle of operation is based on the interference of light which has passed through a coil of long optical fibre as long as 5 km. The development of diode (semiconductor) lasers and low-loss single-mode optical fibre enabled Sagnac effect fibre optic gyros to be developed as practical devices.

Basic compass



Basic compasses usually have:

• **Magnetized needle** — rotates freely when compass sits on flat. It usually has the red end pointing to the strongest magnetic field, which is usually the magnetic North Pole. Magnetic north is different from true north where all longitude lines meet and the Earth spin line goes. Magnetic north lies at North Eastern Canadian Arctic. True and magnetic north are separated by more than 1,000 miles or 1,600 km. When working with a map pay attention at declination markings because of this reason.

• **Housing**: The Capsule that contains the needle and usually damping fluid to help needle settle faster then air filled container would do. Fluid is nonfreezing as it should stay operational even at low temperatures. Bubbles

may form at low temperatures but it will not affect accuracy. You can easily shake them of needle anyway. Bubbles disappear at normal temperature and altitude.

• **Bezel ring**: A rotating ring marked with degrees from 0 to 360. The bezel ring is used for navigation. It preferably has 120 clicks, each of which equals 3 degrees of declination. Clicks are more important at night when vision is limited.

• **Base plate**: The base plate is usually rectangular and preferably has transparent base where the capsule sits. Compasses should have scales as well as rulers in inches and centimeters on straight edges of plate. These are used for measuring distances and driving lines on a map. Select compass with suitable scale for your map.

• **Orienting lines** are marked on the floor of the compass housing. Lines rotate with the housing when the dial is turned. It is used to orient a compass to a map.

• **Orienting arrow** is to be matched with needle when orienting or operating. Sometimes used for declination correction.

• **Index line** is to ease degree reading for direction-of-travel.

• **Direction-of-travel arrow** is to point the way.

Advanced Compass

More advanced compasses have:

• **Declination** or **Variation**[3] **adjustment**: The orienting arrow can be rotated and adjusted for true and magnetic North declination. Often small tiny tool is attached to compass for small regulating screw. Orienting arrow must be offset from magnetic north as much as needed for particular place. Magnetic declinations are usually found on topographic maps.

3 Technically Declination includes both the variation and dip of the magnetic field. Not to be confused with Deviation, which is a term that refers to the effect of ferrous metals.

• **Magnifying lens**: It comes handy to better read dial or for reading tiny map symbols .

• **Sighting mirror**: Mirror can help with reading dial and sighting landmark through notch simultaneously. It also can work as signaling device in trouble or personal mirror.

• **Luminescent markings**: Luminescent markings are seen on north needle, cardinal markings and sometimes on whole bezel. Phosphorus is used as usual but on more advanced models for military use, like Cammenga makes for US army, tritium is used that does not need to be charged for tens of years.

• **Inclinometer** or **clinometer**: Allows to measure angle of slope, steepness or tilt. Not a must but nice feature to have. Could be used to measure slope of terrain or elevation of objects.

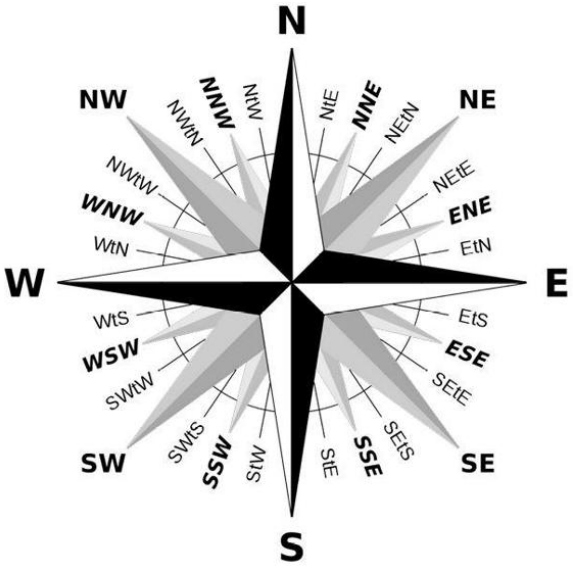
• **Global needle**: In the Southern Hemisphere magnetic field can drag needle to the floor and make it impossible to function. Global needles are compensated and operational on both Hemispheres. Suunto compasses are known for their global needles.

• **Special sights** to improve aiming at distant objects.

• **Transit lock** or **needle-lock**: It lifts the needle off the pivot. This prevents wear of the pivot and fixes bearing that has been taken. Liquid filled compasses do not have locks.

Compass Rose

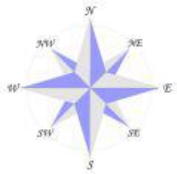
A **Compass rose**, known as well as **Windrose** is diagram present on most compasses. They are often found on maps and are used in symbols worldwide. Four **cardinal directions** — North, East, South and West — and their **intermediaries** are displayed.



They appear as:

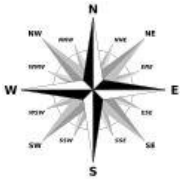
4-point: North, East, South, West, with angles of difference at 90°. (**basic winds**)

8-point: The four cardinal directions (N, E, S, W) plus the four intermediate or intercardinal directions. North-East, South-East, South-West, North-West (NE, SE, SW, NW) at angle difference of 45°. (**principal winds**)

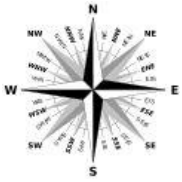


16-point: At angles of difference of 22½° directions are combinations of Cardinal and intercardinal directions. Cardinal directions are mentioned

first. North-northeast (NNE), South-southwest(SSW), East-northeast (ENE) and so on. (**half-winds**)

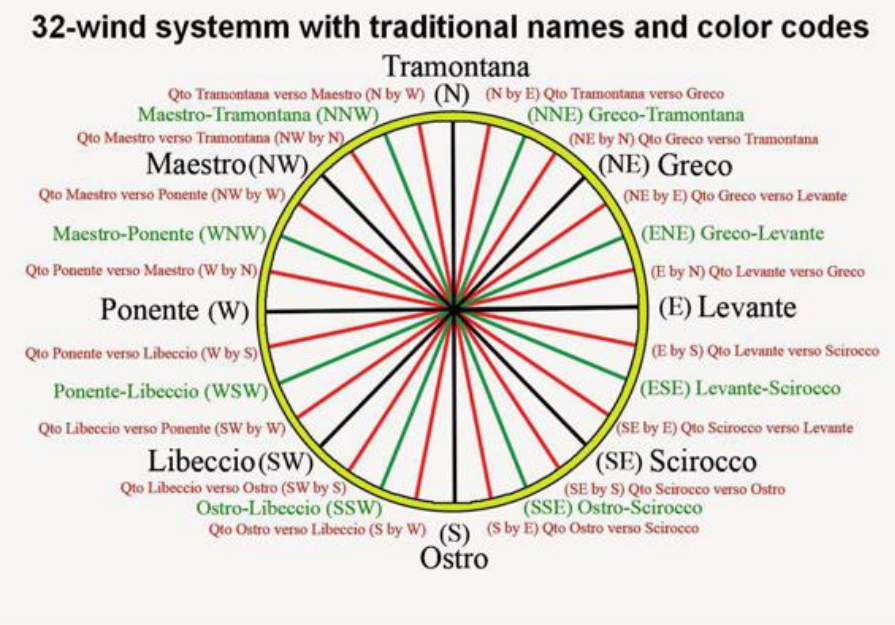


32-point: At 11¼° angles of difference directions are named by first mentioning the closest cardinal or intercardinal direction and then cardinal direction towards which it declines. Like closest to North and declined to East (11¼°) would be called North-by-east (NbE or NtE). The closest to South-West and declined to West would make Southwest-by-West (SWbW or SWtW). (**Quarter-wind**)



Compass rose is named as it is on compass and looks like rose(maybe), but why call it wind rose?! Most ancient human communities had their directions. Usually four directions and they would be local geographical objects, like see or so, but sunrise and sunset was not unnoticeable as for East and West. And for North and South were winds commonly. Ancient Greeks had 12 wind-rose system which was adopted by Romans who came up with their 24 directional wind system. But Mediterranean seafarers came up with their own 8-wind system. Here are the names:

- (N) Tramontana
- (NE) Greco (or Bora)
- (E) Levante
- (SE) Scirocco (or Exaloc)
- (S) Ostro (or Mezzogiorno)
- (SW) Libeccio (or Garbino)
- (W) Ponente
- (NW) Maestro (or Mistral)


32-wind systemm with traditional names and color codes
Tramontana
Qto Tramontana verso Maestro (N by W)
(N)
(N by E) Qto Tramontana verso Greco
Maestro-Tramontana (NNW)
(NNE) Greco-Tramontana
Qto Maestro verso Tramontana (NW by N)
(NE by N) Qto Greco verso Tramontana
Maestro (NW)
(NE) Greco
Qto Maestro verso Ponente (NW by W)
(NE by E) Qto Greco verso Levante
Maestro-Ponente (WNW)
(ENE) Greco-Levante
Qto Ponente verso Maestro (W by N)
(E by N) Qto Levante verso Greco
Ponente (W)
(E) Levante
Qto Ponente verso Libeccio (W by S)
(E by S) Qto Levante verso Scirocco
Ponente-Libeccio (WSW)
(ESE) Levante-Scirocco
Qto Libeccio verso Ponente (SW by W)
(SE by E) Qto Scirocco verso Levante
Libeccio (SW)
(SE) Scirocco
Qto Libeccio verso Ostro (SW by S)
(SE by S) Qto Scirocco verso Ostro
Ostro-Libeccio (SSW)
(SSE) Ostro-Scirocco
Qto Ostro verso Libeccio (S by W)
(S)
(S by E) Qto Ostro verso Scirocco
Ostro

West European names for directions is thought to be originated from Frankish king Charlemagne — Nord, Ost, Sund and Vuest.

Scales

Different measure units

There are different measures in use. These are: **Degrees**, **Mils**, **Grads**, **Point** directions, **Rhumbs** and **Hours**.

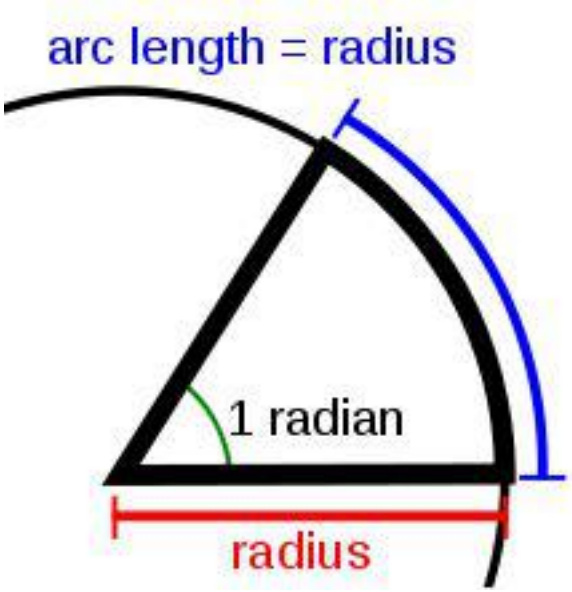
360° **Degree** scale is the most common unit of angle measurement. The compass is divided into 360 degrees clockwise. Each degree is divided into 60 minutes and each minute into 60 seconds. Magnetic compass precision hardly goes in minutes.

Mils[4] are used basically by military. Compass is divided into 6400[5] mils. For simplification some military reduce it to 6000 that is very compatible with 60 minute clock face where 1 minute would make 100 Mils.

4 Mil is a short name for a milradian. 1/1000th of a radian. A radian is an angular measurement that is equal to the angle formed at the center of a circle by two radii cutting off an arc whose length is equal to the radius. Circle length equals to 2pi*radius. How many radians are in a circle? To find out lets divide 2pi*radius by radian(2pi*r/r). As we already know radius and radian are equal. So we have 2pi(pi=3.14159). 2*3.14159= 6.28318 radians in a circle, or ~6283 miliradians. If we divide 360 degrees by 6.28318, we find out that there are 57.2958 degrees in a radian. You can further calculate how many minutes are in 1 Mil. 360°*60’/6283=3.4378 which is usually rounded to 3.44

5 The mil is one thousandth of a radian. The exact figure is 6283, but for simplification 6400 is used, as long as 64 can be divided by 4 and 32 divisions on compass rose can easily further divided into 64.

1 mil represents 1 meter at 1000 meters, 1 yard at 1000 yards, 1 foot at 1000 feet and so on. So if object measures 1 Mil on site at 1000 meters then it should be 1 meter long. If se 4 yard car as 2 Mill then it must be 2000 yards away. You may know estimate size of objects like width of road, height of man and use it to calculate distance using Mil scale measures. 1° equals about 17.8 Mils.



Grads (Gons) are metric measure units and they are seldom in use. Circle is divided into 400 Grads clockwise and Grads are divided into 100 centigrads. East would make 100 Grads, South 200 and so on.

Sometimes only **Points** are present on compasses, like North, East, South and West. Intercardinal points may be present as well - North East, South East, South West, and North West.

On windrose we have seen compass divided into 32 **Rhombs**. Each Rhomb equals 360°/32= 11.25°.

Some compasses, in 19th century, had featured division into 24 **Hours**, thus twice 12 Hours.

Declination

Compass needles point to the north, but it is the magnetic North that is close to true north, but not exactly on top of it. This gives us the magnetic declination. This declination is basically an angle difference between true north and magnetic north that compass needles point. This angle varies from place to place over the world and it changes over time.

So your compass does not really point to the True North Pole, it does not even point the Magnetic North Pole (Magnetic Meridians) and in the future it will point different from today.

Terminology

Declination, variation and deviation are used to describe the angle between magnetic north and true north. Let’s see the differences between these terms.

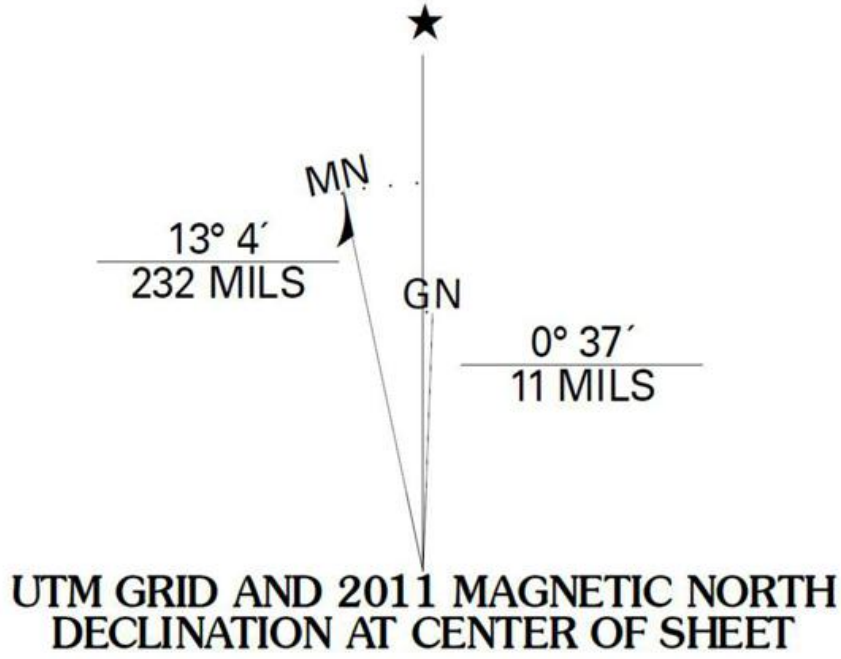
Declination is the term preferred with the magnetic field. The term most commonly used by land navigators. "Magnetic declination" is used as well.

Variation is preferred by mariners and pilots because the word "declination" has other usage in astronomy (the angle of a star or planet above the celestial equator). "Variation" is used to refer to time changes in the magnetic field as well.

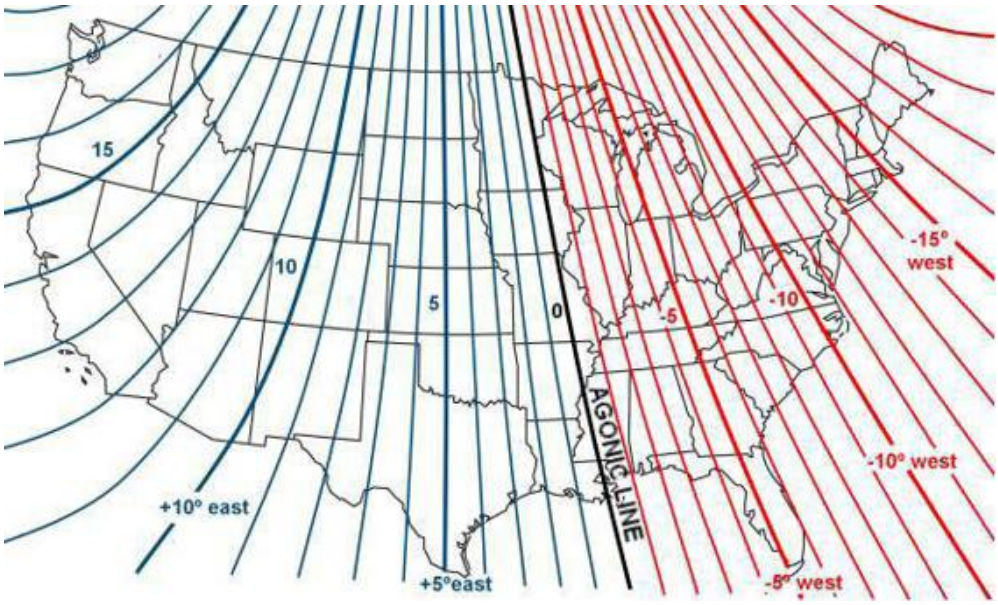
A compass is influenced by the magnetism of the iron used in the construction of the vehicle (ship, aircraft…) as well as the Earth's magnetic field. This causes directional error called "deviation". Deviation should not be used to mean declination.

The Three North

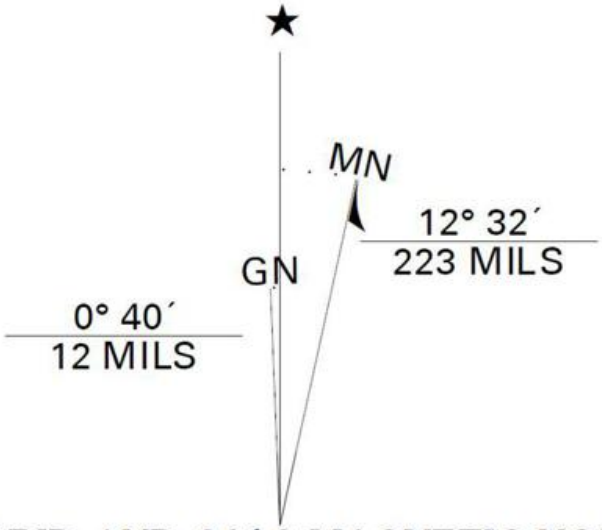
Two north poles are marked on maps as **Magnetic North**(MN) and **true North**(symbolized by polar star). Here comes one more North into play. This is **Grid north**(GN). Grid-lines are not exactly parallel to true north because of technical issues in map making. Maps are flat unlike the globe like earth and because of this Grid North is bit declined from true North. Here you see declinations at **New York**. Magnetic north is declined by 13º 4’ to the west and Grid North is by 0º 37’ to east. So the difference between MN and GN would be 13º 41’ or ~14º. This should be taken in account wile working with map and compass.



Magnetic Declination Basics

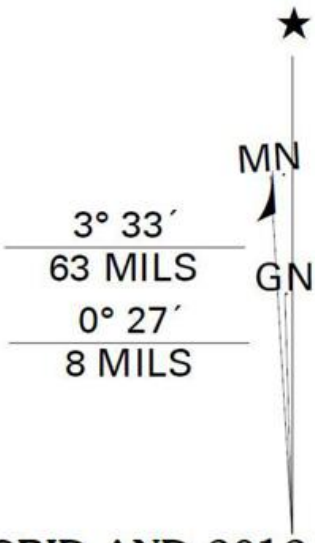


• In **Los Angeles** if facing true north, magnetic north would be slightly to your right (east) by about 13 degrees. This is where your compass needle would be pointing.



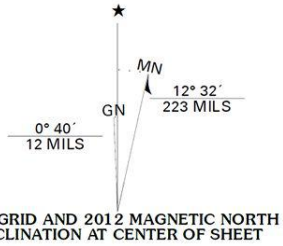
UTM GRID AND 2012 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

• However, in **Chicago, IL.**, you would discover that magnetic north would be almost along the same line (known as the **Agonic Line**, where declination is 0 degrees).

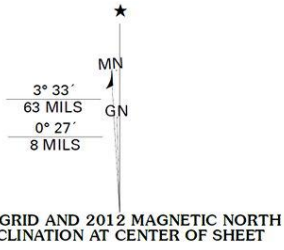


UTM GRID AND 2012 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

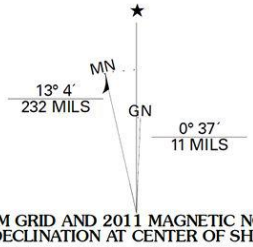
• Pay attention at all 3 side by side.



UTM GRID AND 2012 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET



UTM GRID AND 2012 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET



UTM GRID AND 2011 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

People navigate successfully with maps and compasses all the time. This is called knowledge. You simply learn the angle of declination for the area and then make sure to take that angle into account when making navigation calculations. Some compasses can be adjusted for declination for an entire trip.

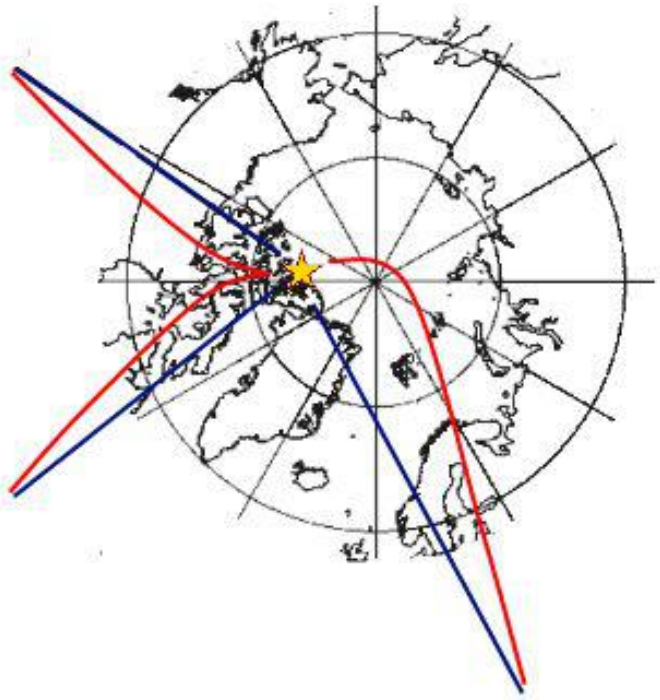
Declination Changes Over Time

The earth's magnetic field is on constant change, a process known as secular variation. Our planet's outer core contains complex fluid currents of iron, nickel and cobalt that generate a magnetic field and this field poles do not coincide with true north or true south.

The compass user should always use the latest declination information printed on topographic maps. But this declination information can quickly become outdated. So you should make sure to use the newest map possible, include annual changes in your calculations or check magnetic declination online at NOAA's National Oceanic and Atmospheric Administration or other sites.

Magnetic Meridians

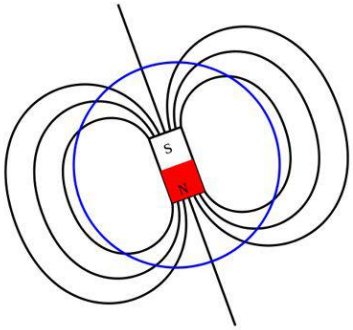
Declination is actually the angle between the magnetic meridian and the geographic true north meridian at a given location. Declination can vary considerably along a magnetic meridian as shown on image.



Magnetic meridians do not converge radially on the North Magnetic Pole. Contrary to popular belief, a compass needle does not point directly to the North Magnetic Pole. However, if you follow the direction your compass needle points, you will eventually reach the North Magnetic Pole, but not by a direct route. The diagram clearly shows that the magnetic meridians (curved) diverge considerably from the direct path to the Magnetic Pole (strait lines). The European example is particularly interesting. At Scandinavia the difference is about 20 degrees off course, and at 80º North it gets almost 50 degrees off course.

Inclination or Dip

Magnetic inclination or **magnetic dip** is the same and it is an angle between the horizontal plane and the magnetic field vector (Earth's magnetic field is a vector quantity). So this shows that the earth magnetic field pulls down the compass needle and this is truer when you move closer to magnetic poles. Actually hundreds of miles/kilometers around magnetic poles compasses point down and are worthless and next hundreds of miles/kilometers they are unreliable. Between the magnetic poles there is the magnetic equator where inclination or dip is zero. And north from this equator the compass needle north end is pulled down and south from it the southern end of needle gets pulled down. In general, the earth has 5 different **magnetic "dip" zones**. Contiguous United States falls within the same magnetic dip zone as an example.



Local Anomalies

Position on earth has magnetic declination as we know but Local Magnetic Anomalies originating in the upper mantle, crust, or surface of earth distort predicted declinations. Ferromagnetic ore deposits are good examples. Volcanic origin faults and lava beds, ridges, trenches, mountains, fulgurites after lightning, power lines, pipes, rails and large buildings frequently induce error of 3-4 degrees.

At some places on Earth the field is vertical and a compass points straight up or down. This is the case at the magnetic poles but there are other locations where extreme anomalies create the same effect.

Compass Use

Compass Use

Compass can be used for multiple purposes, with map or without. Compass can be used to:

- Determine direction of travel
- Determine direction of object from you or vice versa
- Align or Orient map with actual land
- Determine your position on map using two known objects by Triangulation.
- Determine position of an object on a map.
- Measure Distance to objects

Accurate reading

Compass reading must be as accurate as possible as a small error on increased travel distance can result in significant measurement error. So follow the following rules as much as appropriate for your situation.

- Hold the compass level and steady.
- Raise and lower eyes when taking a bearing, do not move your head; use the same eye.
- Try to directly face measured object.
- Avoid taking readings near magnetic fields and ferrous metals such as steel, iron, vehicles, rebar, and even clipboards.
- Take bearing several times.
- Keep magnetic declination in mind.
- Use back bearings to ensure you are on correct track.

Orienting compass

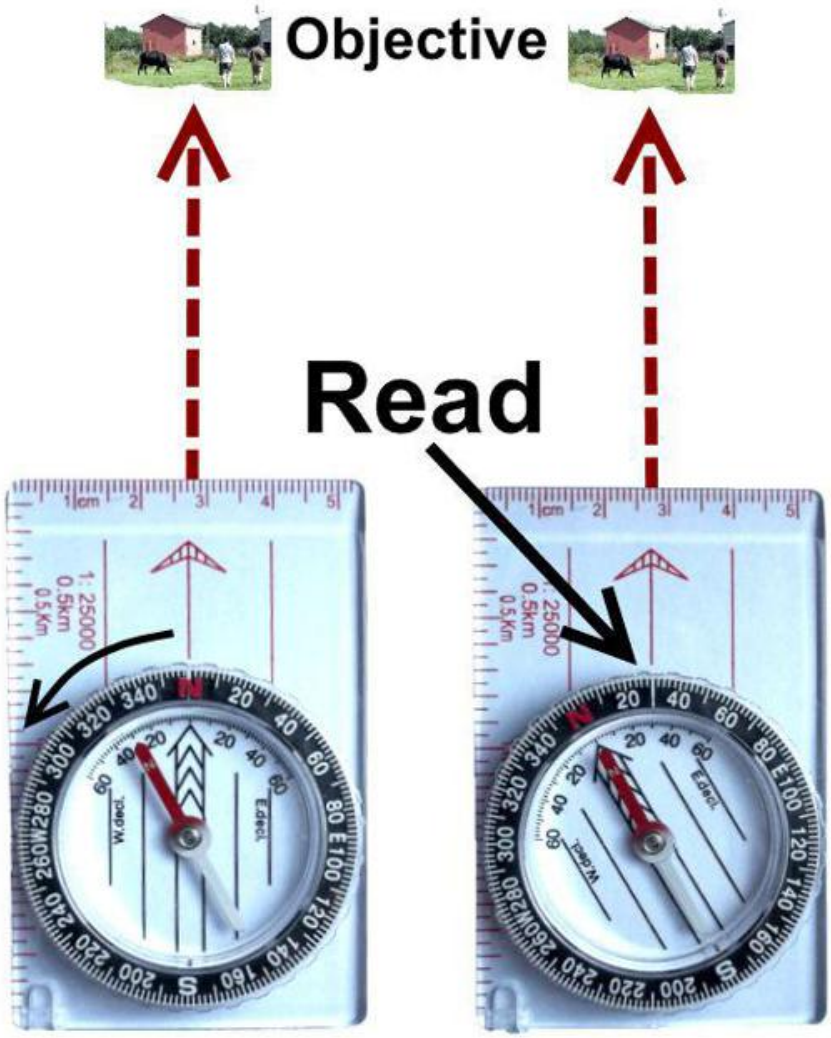
Orienting compass means aligning north seeking end of the needle over orienting arrow also known as "**boxing needle**". The purpose is to know position of yourself and other objects in relation to north. This is the use of compass at all. Compass could be oriented to magnetic or Geographic north.

Taking and following bearing

Taking bearing means measuring direction from one point to another and it is expressed in angle degrees. If compass was not adjusted for declination then it will be “magnetic bearing” in contrast to “true bearing” with adjusted magnetic declination. Taking direct bearing is very simple.

1. Face the object and point direction-of-travel arrow to it.
2. Turn the dial until the needle and orienting arrow are aligned so called “boxed” (orienting compass).
3. Read bearing at index line.

This is magnetic bearing. To adjust for declination you must **add for west** and **subtract for east** declination.



This reading is the direction of object in angle degrees.

A **back bearing**, often called **backsighting**, is the opposite of a bearing. It is measured from the object to your position. The back bearing differs from bearing by 180°. To determine back bearing you can:

1. Align south end of needle with orienting arrow and read at index line, or

2. Calculate by adding or subtracting 180°. If direct bearing is more then 180° you should subtract 180°; if it is less then 180° then you should add.

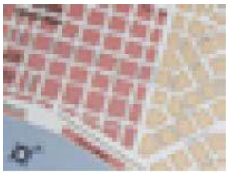
Back bearing is very important as it can be used when you communicate your location from someone else or when navigating and you want to make sure you are on correct track.

Direction of object and direction of travel

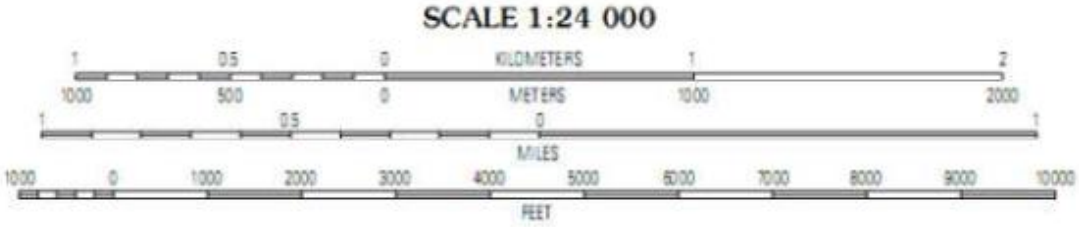
You can check your direction of advance in case you don’t see other marks. Imagine you are heading to the hill you see in front of you, but there is a forest between you and the hill. You see the direction of the hill on the compass before advance and wile in woods when you have no sight of the hill you can use your compass to make sure you are heading the correct and as well the shortest direction. If the hill was at 100 degrees from the north, then in the woods you would ensure that you are heading 100 degrees from North.

How this should be done? It is very easy. You just point the compass to your desired direction and align Red North needle with North (N) on compass as you turn the dial. You then read the direction at index pointer.

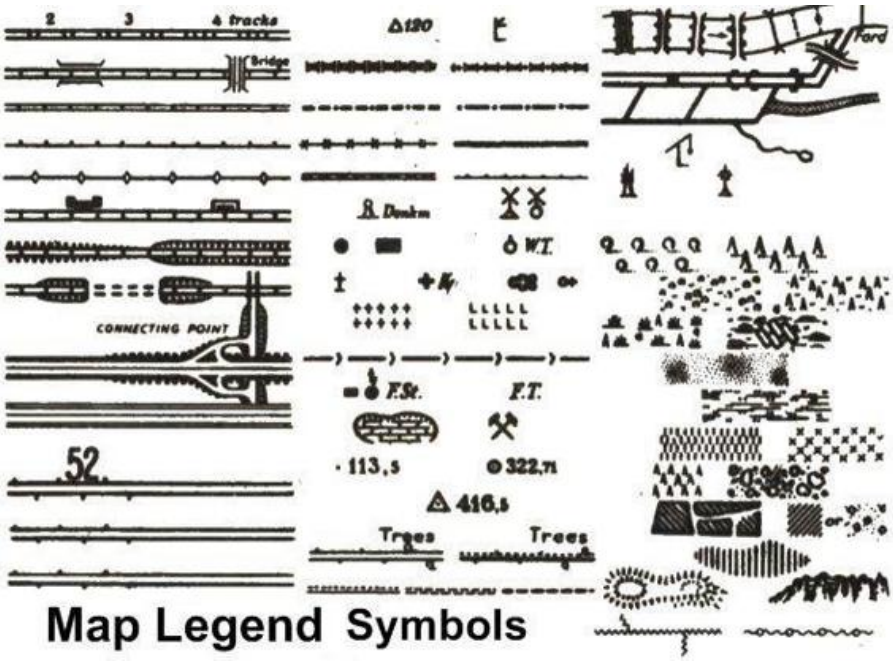
Map



Map is a representation of a region of the earth(or heavens) usually on a plane surface. Reading map is easy. There are some general rules they follow. The North is at the top and South at the bottom, West to the left, and East to the right. Every map has a **scale** to show how the distance between two points on a map relate to the distance between those two points on the earth.



Maps have special symbols to represent real-world things like roads, rivers, hills, populated areas and more. A map has Legend for the symbols it uses.



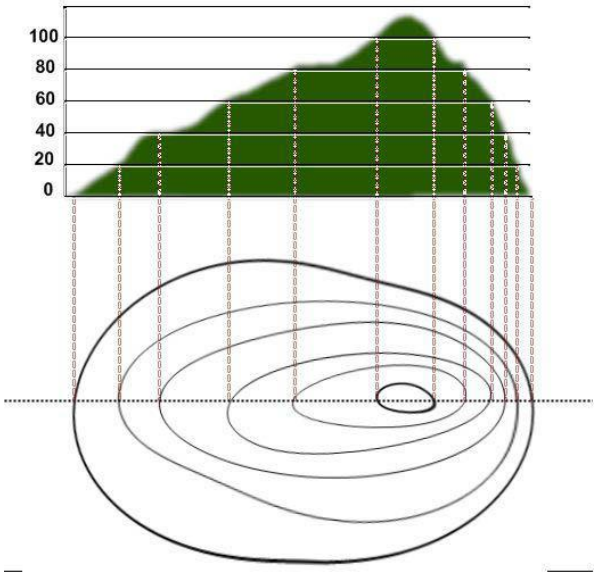
Colors are used for extra information to show like blue for water(river, lake…) and green for vegetations. Light green is used for low-lands and darker green for elevations. For higher elevations light and then dark brown would follow on **physical maps**.[6]

6 Maps called choropleth maps use map color to represent statistical data, like you would see during elections.

There are different types of maps used for different purposes, like Political, Physical and so on. But with compass the most useful type is **Topographic map**(**topo** for short) as it shows land topography[7] — surface shape and features of the Earth.

7 From Greek τόπος topos, “place”, and γράφω graphō, “write”

The most appropriate one to use with compass is a topographic map; a map showing topographic features by means of **contour lines**. This contour lines show elevations and the elevation changes of the terrain. Curvimeter is used to measure the lengths of these curved contour lines by hand. Close contour lines mean steep slope terrain while distant contour lines mean more flat terrain. Sometimes shading is added to topographic maps to help you visualize 3 dimensional picture of landscape.



Topographic maps have **Title**, usually found in the top right corner. Titles of next adjacent topo maps are found at corners, edges or other visible locations.

Maps have Grid lines, **Latitude**(horizontal) and **Longitude**(vertical) to identify the exact location of any point. The Equator is 0 degrees. As you go north or south of the equator the, latitude increases all the way up to 90

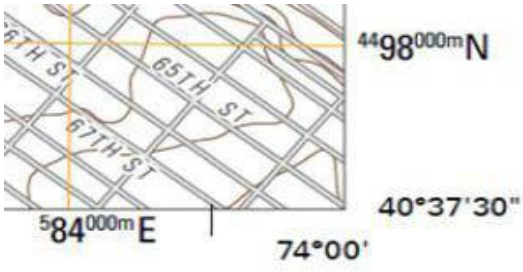
degrees at the poles. Latitude is always given in degrees north or south. Longitude is angular distance measured east and west of the **Prime Meridian**. The prime meridian is 0 degrees longitude. As you go east or west from the prime meridian, the longitude increases to 180 degrees east(eastern hemisphere) or west(western hemisphere).

1° degree = 60’ minutes

1’ minute = 60” seconds

1’ minute latitude, not longitude, equals 1 **sea mile**. It varies from about 1,855.3 metres at the equator to about 1,849.1 metres at the poles (mean value is 1,852.3 metres), as the earth is not perfectly round. **Nautical mile**[8] is used by sea and air navigators.

8 1 Nautical mile or knot = 1852 metres = 1.852 kilometres = 1.151 miles.



UTM (Universal Transverse Mercator) is another grid system that can be used to find position, commonly used in the military and for research. The UTM system divides the surface of the earth into a grid with numbers across(1-60) called the **zone number** and letters up called the **zone designator**.

A position on the Earth is given by the **UTM zone** and then **easting** and **northing** coordinate pair in that zone. The point of origin is the intersection of the equator and the zone’s central meridian. To avoid negative numbers the central meridian of each zone is set at 500,000 meters East, so in any zone an easting of 300,000 meters is 200,000 meters west of the zone’s central meridian. UTM eastings range from about 167,000 meters to 833,000 meters at the equator and narrows towards the poles. The maximum “northing” is about 9,300,000 meters at latitude 84 degrees North(north end of the UTM zones). In the southern hemisphere northings start from about 1,100,000 metres at 80 degrees South(south end of the UTM zones) and increases toward the equator that is set to be 10,000,000 meters. No point has a negative northing value.

Grid zone designation is written on topo maps. Try to find example of 18T 583112 4504995 that will be somewhere on Governor’s Island.

Geoplaner.com is good and easy tool but make sure to master coordinates on paper maps.

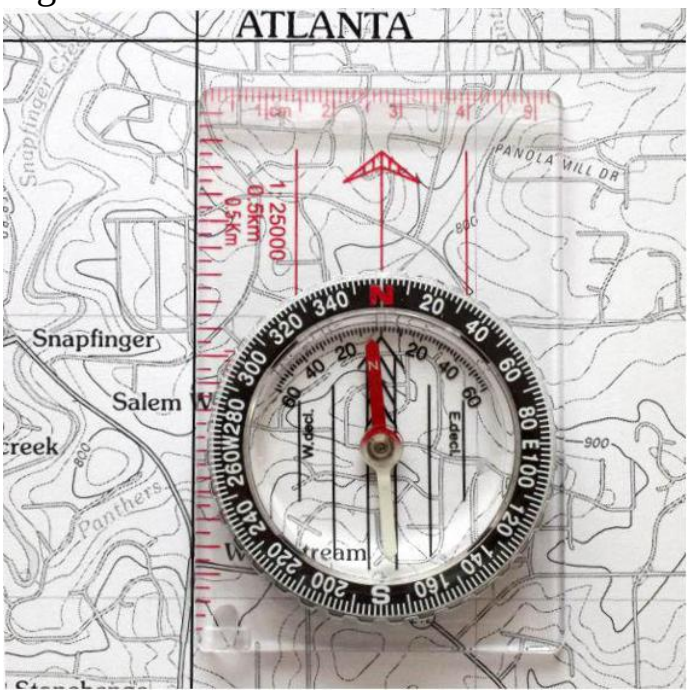
Map and Compass

Orienting Map and Land

Orienting map is easy. Once oriented map is positioned so that map's North is on the real North. To orient a map you can put the compass edge parallel to north-south grid-lines, called Meridians, and turn the map and compass until the compass needle points to the degree magnetic north declination for the map. This declination marking of three North is found on all Topographic maps.

Orienting map is super easy:

1. Rotate compass ring to default position so at index line is North or 0°/360°.
2. Put compass on map with base plate alongside gridlines. Direction-of-travel arrow must be pointing north.
3. Rotate map and compass together until the needle matches orienting arrow.
4. Adjust for magnetic declination.



Map is now oriented and **adjusted** for declination.

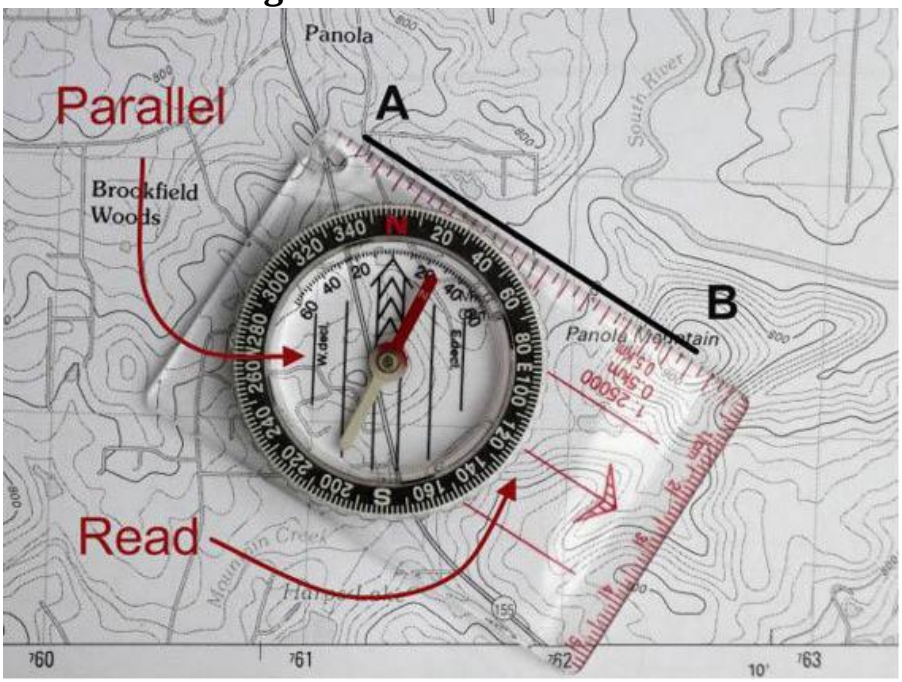
Measure a Bearing on a Map with compass

Measure bearing on a map is easier with protractor but compass could be used as well.

1. Compass should be placed on map with its edge touching bearing line between start and destination point and Direction-of-travel arrow pointing to destination side.

2. Turn the compass ring so that orienting arrow is parallel to longitudinal lines and points north..

3. Read the **true bearing** at index line.



This is the true bearing for the destination point but you may want magnetic bearing. If your compass is not adjustable to declination it is more useful to know magnetic bearing and follow it. So you can easily calculate magnetic bearing. If declination is to **east** you should **subtract** and if declination is **westward** you **add**. For example if magnetic declination for area is 6 degrees west and true bearing is 40 degrees then the magnetic bearing is 46°. **This is opposite from magnetic to true conversion!**

On picture above – if you are at cross-roads (**A**) and want to go to Panola mountain top (**B**) you can measure bearing and as you see at index line the reading is 120°. You want to convert that to magnetic bearing. Declination

for the region is 6° east. So you subtract and follow magnetic 114° on your compass to get from **A** to **B**.

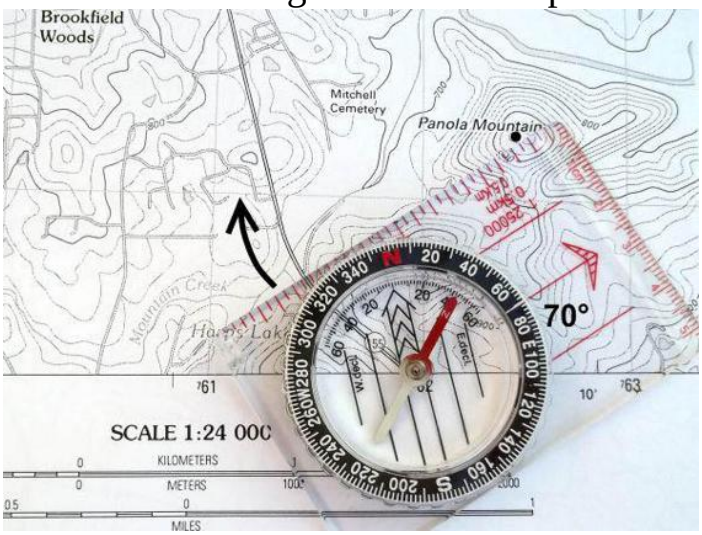
If your compass is adjustable to declination then you can adjust it and then follow the above 3 steps.

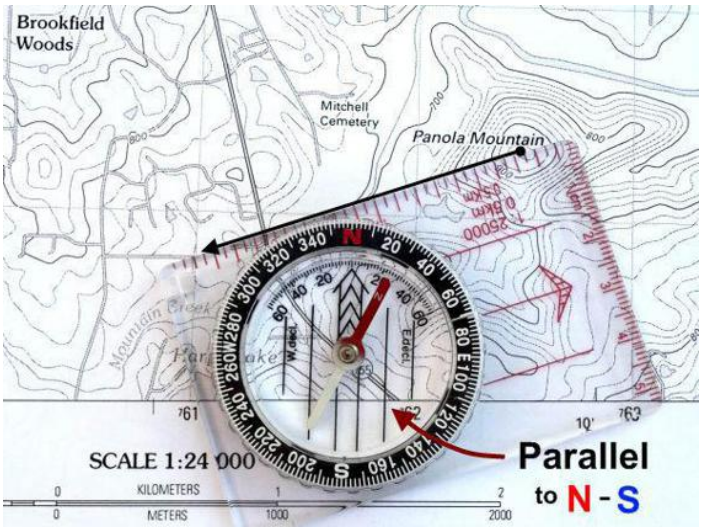
Compass bearing on map

After accurate reading on compass it is easy to transfer bearing on a map using compass.

1. First, take a bearing reading of the object.
2. Calculate for declination (for east declination add; for west subtract)
3. Rotate the compass ring until you see calculated(measured if compass was pre-adjusted) bearing at index line.
4. Keep one edge of compass base plate on the measured object and rotate entire compass until orienting arrow (points top) and lines are parallel with north south lines on the map.
5. Draw a line along the compass edge on the map starting or passing point from which reading was taken.

Picture below shows 70° bearing transfer on map as an example.

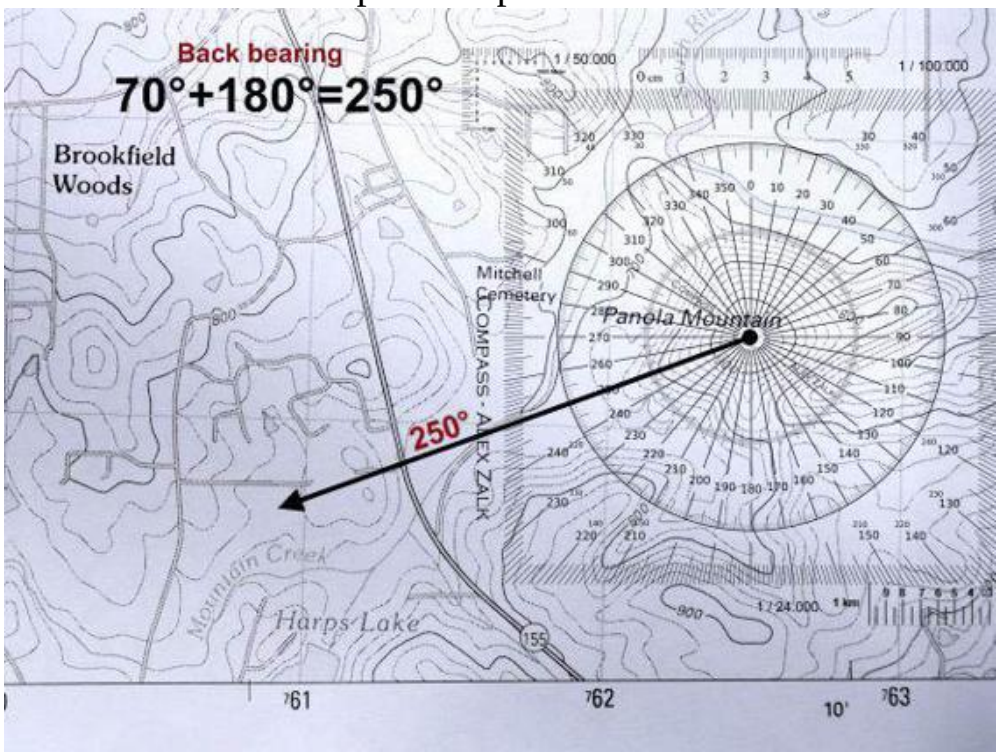




More accurate bearing reading or plotting can be done using protractor.

1. Take bearing and adjust for declination if needed.
2. Transform to back bearing.
3. Center protractor over interest point and orient 0° with true north (grid lines).
4. Mark map at protractors edge at back bearing degree.
5. Draw a line.

Here is the same 70° example with protractor.

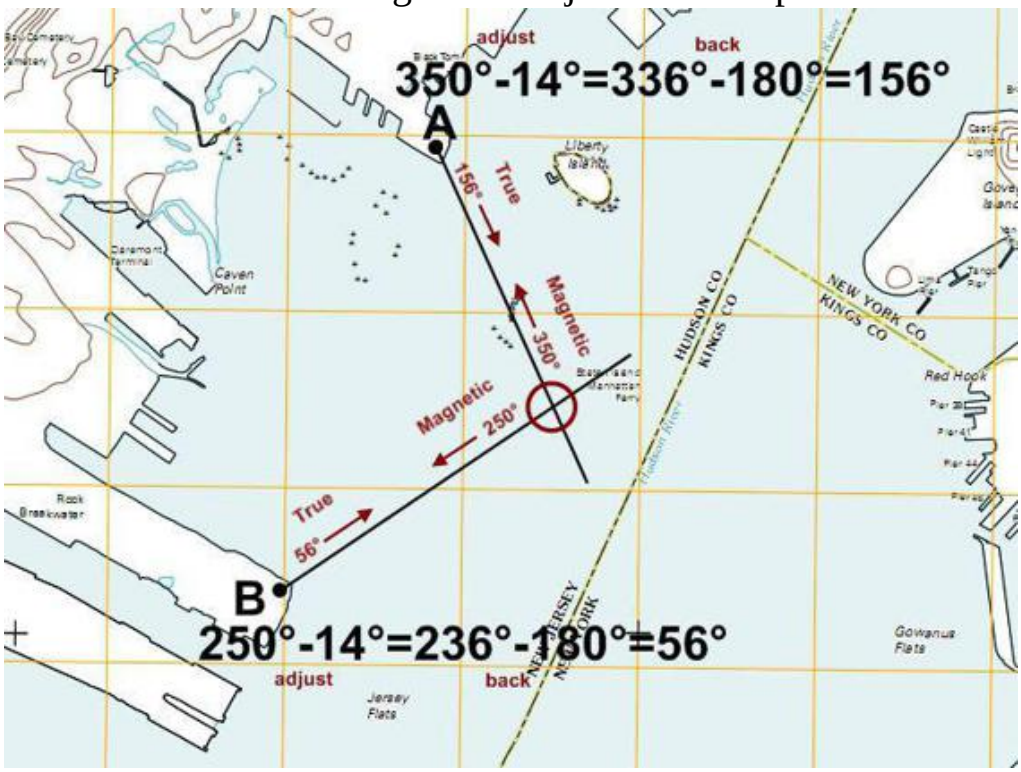


Determine Your Position on Map

There may be times in the field when you do not know your position and/or you may need to communicate your position to others.

Determining own position is fairly easy. This is called triangulation or “resection”. It involves sighting on at least two known landmarks; on two known markers on the map or sometimes even one will do.

1. Take bearings on each object. Convert to true bearing (not magnetic) if needed.
2. Convert to back bearing.
3. Draw lines of back bearings from objects on a map.



Point of intersection of these lines is your position.

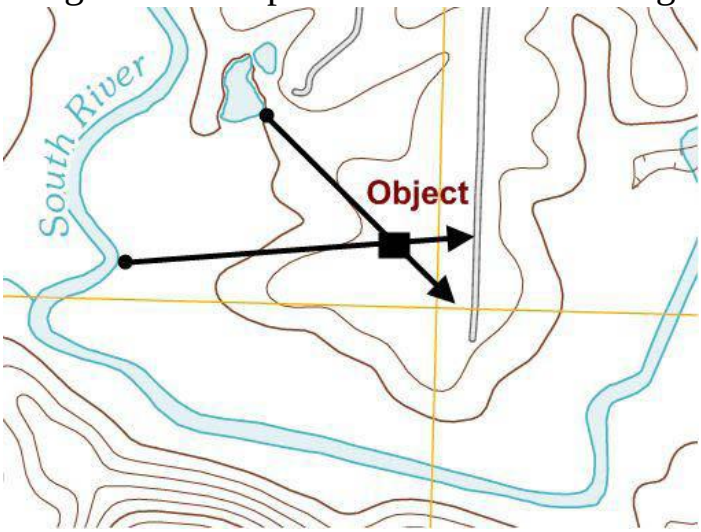
You should grab a compass and a map and try it out. To know does not mean to be able. Confidence comes from practice.

If you are at somehow known feature on a map like river, road or alike you can use only one back bearing to determine your position. For example if you are at river and have 1 back bearing line from object on a map, then you location is where bearing line intersects with river.

Determine Position of an object on a Map

Triangulation can also be used to determine the location of an unknown position. For this purpose bearings must be taken from 2 or more known positions.

1. Take bearing from at least 2 known locations to unknown position.
2. Adjust/calculate for magnetic declination.
3. Transfer bearings on the map and so draw connecting lines.



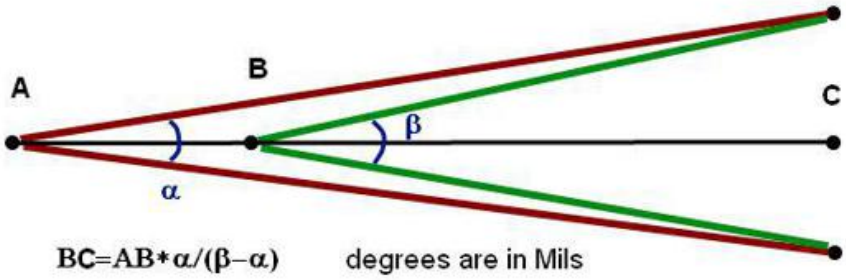
The point of intersection is the location of previously unknown position. (Check coordinates and call for air strike. Just kidding.)

Measure Distance to objects

After you know your position and position of other object on map it is very easy to determine distance to object using map scale and ruler. Compass base plates usually have ruler markings along edges and often map scales for commonly used map scales as well.

Calculations

Distance with angular mils



The division in angular mils makes it possible to calculate a distance even when only few parameter are known.

To measure distance from A to C, one should first measure angles between two visible points of equal distance as C at point A and at point B. distance between A and B should be measured as well. The formula for calculation would be $BC=AB*a/(b-a)$. Angle measures must be in Mils

For example if AB=100m and $a=100$ mils and $b=111$ mils.

$b - a=111-100=11$

$100/11 \approx 9$

$100m*9=900meters$

$AC=AB+BC=100m+900m=1000m$ or 1 km.

So the distance between A and C is 1000meters.

Directions without Compass

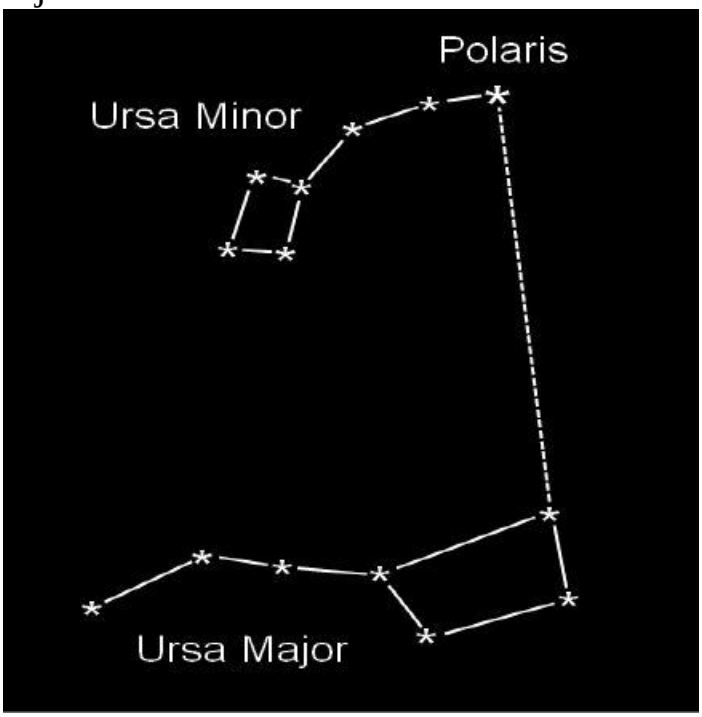
While the compass is an accurate tool as much as simple pocket magnetic compass can tell directions with 1°-2° accuracy it never hurts being able telling directions with less accuracy without any tools. If you have a local **map** and can use features around to orient the map then you know the north. Otherwise, lets just use nature around us and tell the directions.

The sun

The sun comes up on East and sets on West. Who in the world does not know this? It moves from east to west about 15° in hour as 180°/12hr=15°/hr. When the sun reaches the highest point it is on the South. Time should be about 13:00 – 14:00 or 1 – 2 PM.

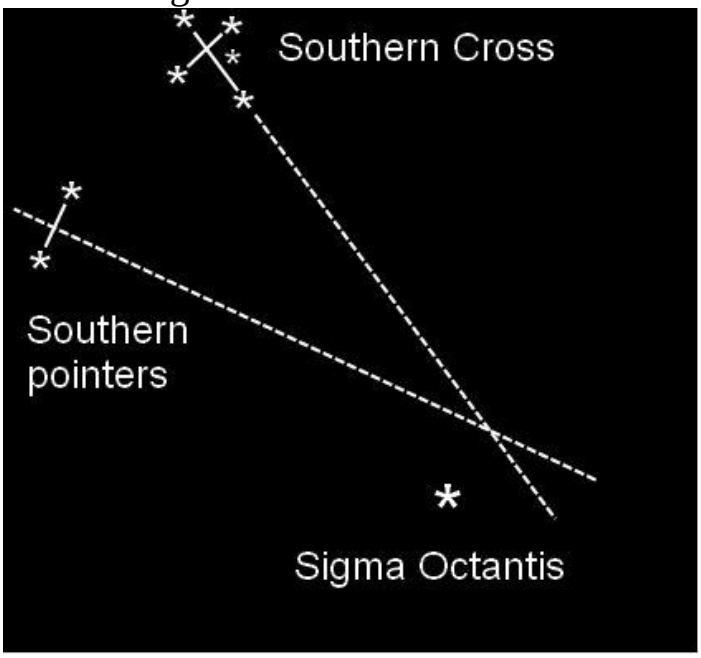
The stars

Well known **Polaris star** is accurate pointer of north. Unlike South pole star it is bright enough and can be seen easily without any aid. Polar star is at about 4 fold projection from the end stars of Ursa Polaris.



Polaris can not be seen from Southern hemisphere and **South pole star** or **Sigma Octantis** is used instead. But it is not bright star, hard to see unaided and projections are used to locate it. Two projections from

Southern Cross and perpendicular projection from Southern Pointers cross near southern pole star - Sigma Octantis.

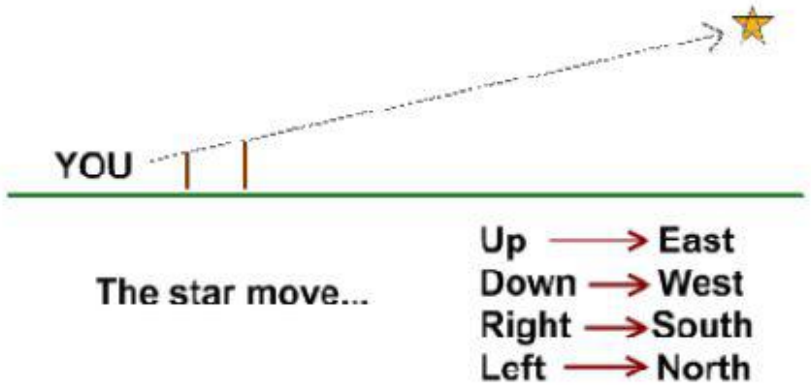


Two stick method could be used to find direction if polar stars are behind clouds.

1. 1. Drive a two sticks in the ground so that the tips of the sticks line up with a bright star.
2. 2. Watch the star for a few minutes to see that the star has moved(because of earth rotation).

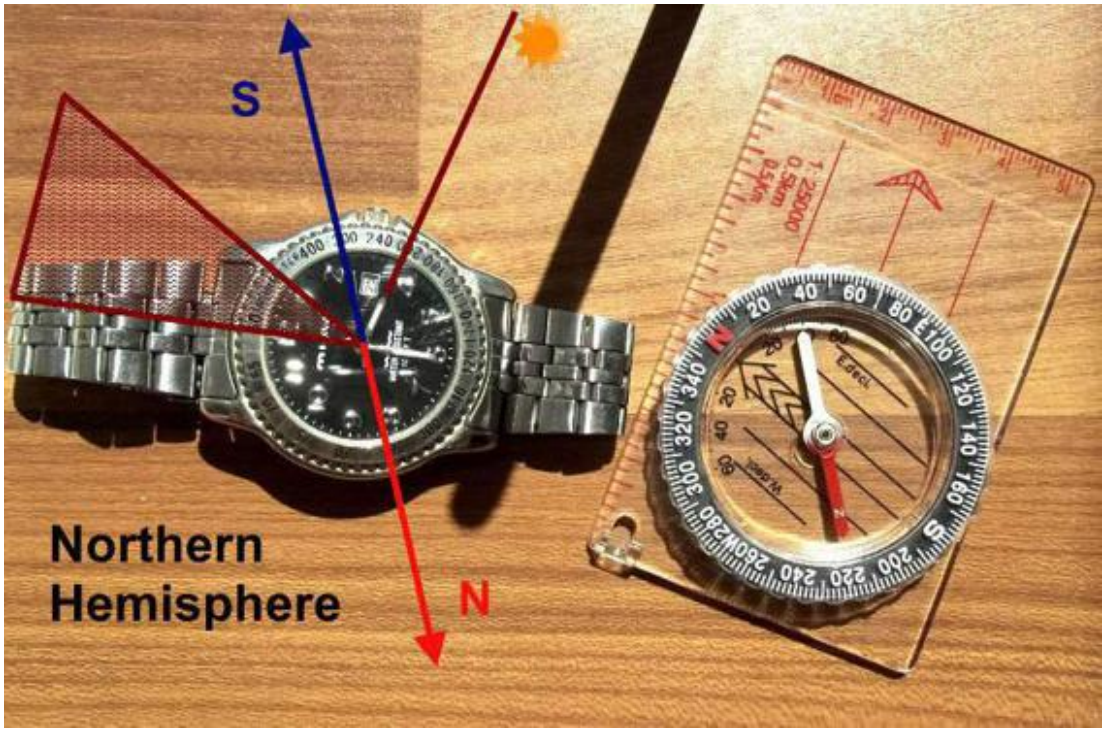
If it seems to move...

- • Up, you are facing East
- • Down, you are facing West
- • Right, you are facing South
- • Left, you are facing North

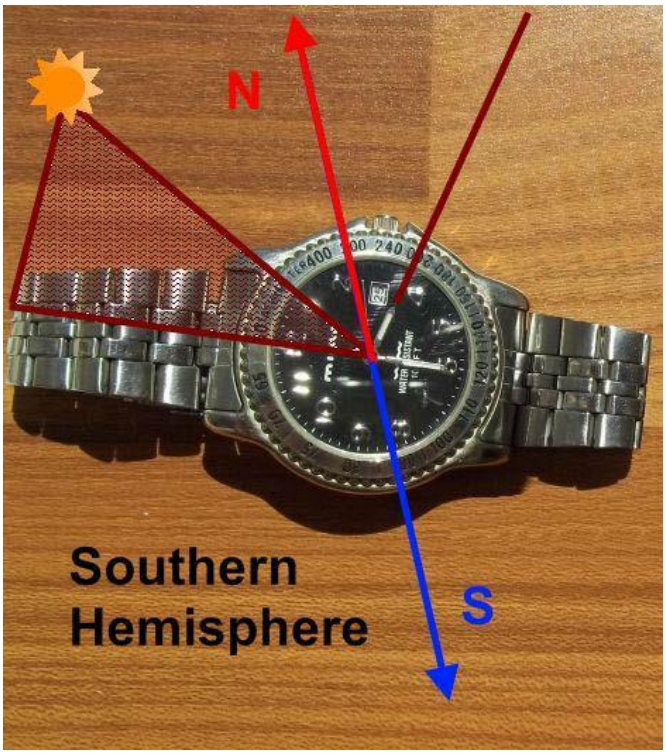


Analog Watch

Analog watch can be used to determine directions. The watch must be accurate of course. Place it on level surface and point the hour hand at the sun. Draw or imagine a line starting from the center of the dial halving the angle between the hour dial and 12 o'clock. This line points south if you are in Northern hemisphere. If you are on daylight saving time it is better to use 1 o'clock instead of 12 o'clock.

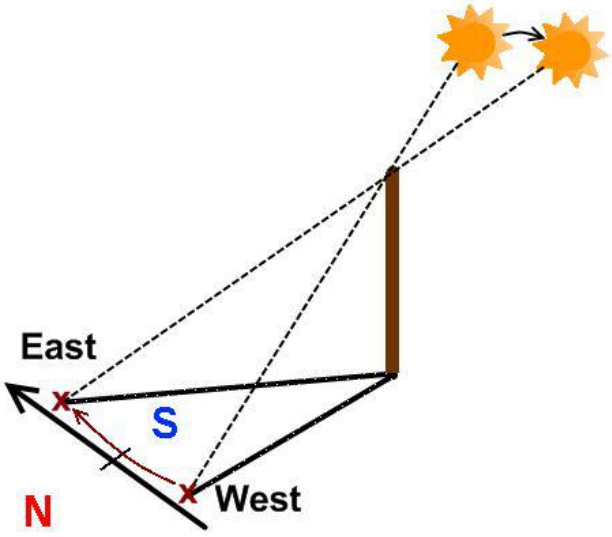


For the Southern hemisphere you point 12 o'clock(1 o'clock for daylight saving time) hand at sun and imaginary line between sun and hour hand would point North.



Shadow-Tip

Place a stick upright or find tall fixed object that you can use its shadow and mark the shadow tip. Then wait for about 15 minutes and observe shadow tip movement **from west to east**. Mark the shadow tip again and draw a line between this 2 markings. This is your east-west line with west on the first mark and east on the second.



If you have enough time you can observe that shadow shrinks before midday and grows after midday. If you measure shadow length and draw a

line between equal length shadows then the directions will be more accurate.

Nature

Nature around can give you a lot of clues.

- • Generally trees grow moss fastest on the shadow side(North in Northern hemisphere) of their trunks.
- • Ants tend to build their hills at the sun-side of trees (South in Northern hemisphere).
- • Deciduous trees tend to grow on the sunny side of hills; evergreens grow on the shadow side.
- • Moss will be greener on the Shadow side and will be yellowish or brownish towards the equator side.
- • Plants tend to grow where the sun is, so abundant vegetation will grow more towards the equator side.
- • Tree rings on tree stomps will be more widely spread on the equator side compared to the side facing the other way.

DIY

How to make a Compass

Emergency compass

If you don’t have a compass or your compass broke you should be able to make one. You can use simple items and make compass that will be quite accurate.

If your compass broke you can still use the needle from it. The needle is magnetized and if you allow it to float freely it is going to show you the directions. Just, take care and protect needle from wind and similar hazards.

It is easy to make compass needle from ferrous metal things around, like:

- sewing needle,
- nail,
- paper clip,
- razor blade or
- small ferrous wire.

They need to get magnetized. Several methods could be used for this purpose.

Tapping – Align needle to north-south line at best you can suppose, hold it 45° against hard wood and tap with your knife blade. This is the last option from my point of view.

Hair – Hold you needle with one hand and stroke it against you hair **in one direction** without hurting yourself until needle gets magnetized.

Silk – Silk works better then hair does. So if you have silk materials around like bags or clothing then like with hair, stroke needle against it **in one direction**.

Magnet – Striking against magnet in one direction is even better. If you have small magnet or can use speaker magnets, do so to magnetize ferrous materials but keep magnets away from compass as it affect accuracy.

Battery – If you pass electric current around ferrous materials they get magnetized. You need insulated wire for this. Your headphones could be the source of wire in case you don’t have other source. Cover the needle with paper or plastic to insulate it. Then wrap wire around it tightly full length and connect it to power source. Battery will get warmer indicating the process was achieved.

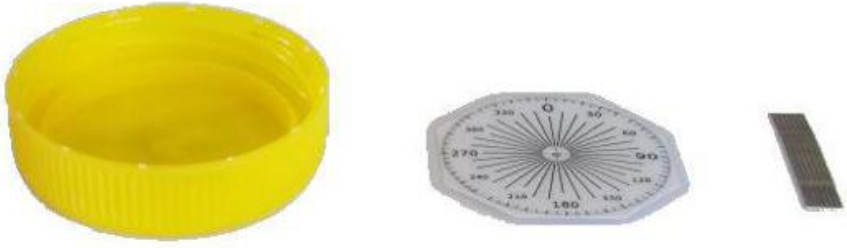
Needles magnetized like this are very weak. You must protect them 100% from wind and wait sometimes for up to 15 minutes to see them oriented.

All this is about emergency DIY. Lets see here normal easy Compass DIY.

Simple homemade compass

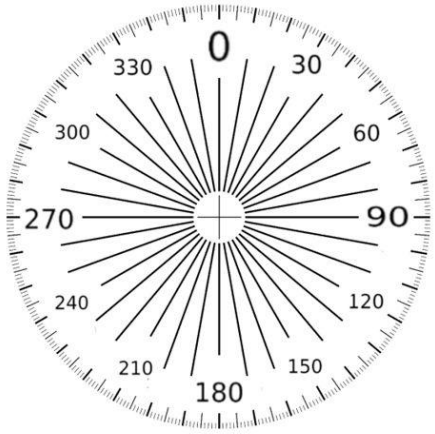
You need:

1. A wide bottle cap
2. Thin transparent plastic film or board
3. Small ferrous metal rod
4. Glue
5. Printer



You may need a thermal laminator as well if your printer can not print on plastic paper.

Here is what you can print:



If your printer can print on plastic you can go for plastic, but if you can only print on paper like I did on above picture than you will have to laminate it.

For ferrous needle you can use metal paper clip or stapler staples. They must be magnetized. Just put them on magnet along North-South line and leave for couple days. They should be tested for accuracy before they are glued under compass dial.

Compass dial and needle test on water.

When magnetic rod is ready you can glue it under the dial. I used silicon based glue.

Make dial as round as possible.

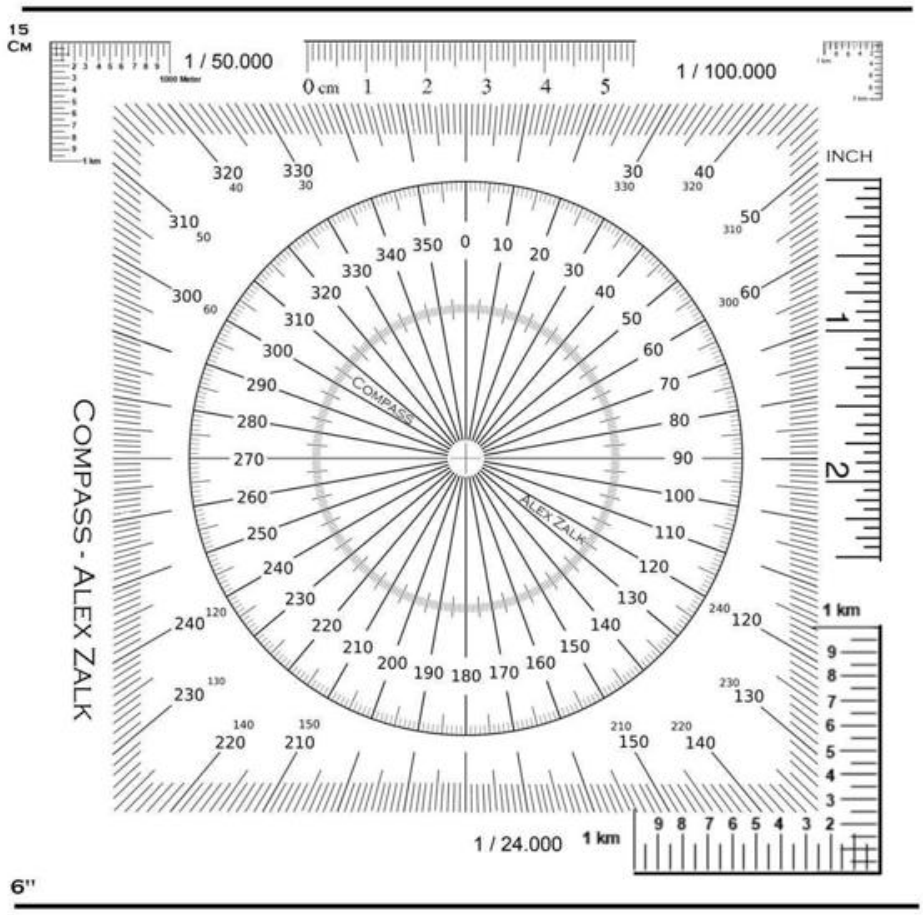
Fill the wide bottle cap halfway or so with water and put compass dial, with magnetic rod under, on water. It should float and be centered. Surface tension of water keeps water edges up and thus pushing the dial to the center. Make the compass dial as round as possible so surface tension will have minimal effect on rotation and it will rotate freely. You can adjust(lower) surface tension by adding some soap if you need to. I never did.

At the end thin transparent plastic glass can be tight glued on bottle cap.

Finish edges and the compass is ready. This compass is very simple. So, even if it breaks any part of it easily repairable and replaceable.

How to Make a Protractor

This book makes making protractor real easy. You just need a decent printer that can print on transparent plastic paper. Or you can print on imaging paper with any printer and laminate it. Pay attention and make sure to scale it correctly to be able to use it topo map gridline boxes.

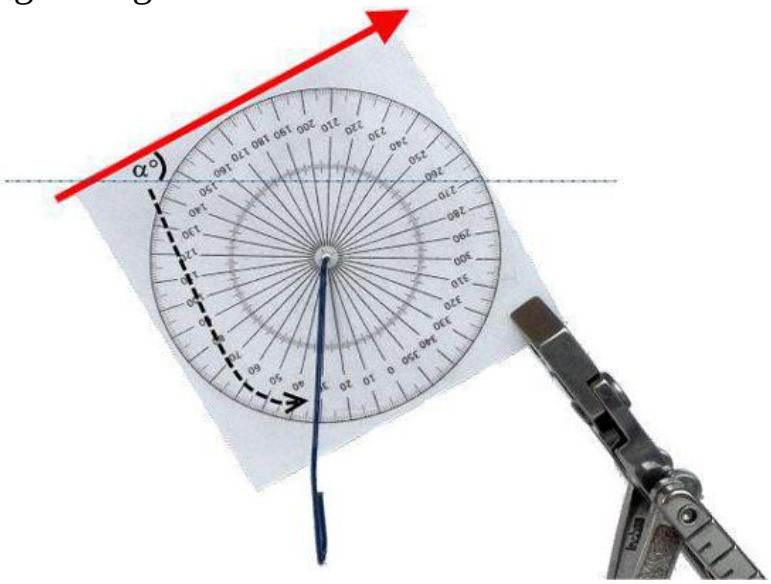


You are free to use this Protractor image as you wish as long as you keep visible sign “Alex Zalk” and “Compass” on it. Can be downloaded here.

How to Make a Clinometer

Making clinometer is super easy as you may ignore scale while printing.

1. Just print the above protractor image;
2. Make hole in the very middle;
3. And let weight hang from the middle hole.



You are done.

Slope is usually expressed as degrees (°) or percentage (%).

Popular compass manufacturers

Cammenga as the official supplier of the Tritium Lensatic Compass to the U.S. Military is very popular compass manufacturer.

Brunton is another famous US compass manufacturer.

K&R is a German manufacturer of precision compass products.

Suunto is Finnish compass manufacturer famous for its global needle compasses.

Silva — Swedish orienteering compass maker.

Do you need one?

A topographic map and compass are still the primary tools for navigation even in this GPS era. Why? Because they do not depend on batteries and satellite signals. **In wilderness you need tools that won’t let you down no matter what**.

Appendix
Compass Tips and Terminology

Tips

• Ferrous metals and electric fields distort a compass reading. So when taking bearings try to stand away from car, APC, running engine or other electric devices. Metal rods in concrete can distort reading as well.

• Do not store a compass near magnets or strong electric field. Speakers with a powerful magnet for example. Do not place compass next to cell phone. Such exposure could demagnetize the needle over time. Needle responds to all near magnetic fields and you want the strongest to be from the earth.

• Be aware of regional magnetic zones. Compasses need to be appropriate for the latitude. In general, the earth has 5 different magnetic "dip" zones. Some areas can cause a compass needle to drag against the housing, affecting the accuracy of a bearing.

• To avoid confusion when communicating with others express all bearings with the north references. For example: 30 degrees true; 10 degrees magnetic.

Terms

Altitude – Altitude or height is defined based on the context in which it is used (aviation, geometry, geographical survey…). As a general definition, altitude is a distance measurement, usually in the vertical or "up" direction. Altitude is commonly used to mean the height above sea level of a location, in geography the term elevation is often preferred for this usage. So altitude is distance above sea level.

Vertical distance measurements in the "down" direction are commonly referred to as **depth**.

Azimuth – An azimuth /ˈæzɪməθ/ (from the Arabic السمت as-simt "direction") is an angular measurement in a spherical coordinate system.

In land navigation, azimuth is usually denoted as alpha, α, and defined as a horizontal angle measured clockwise from a north base line or meridian. Azimuth has also been more generally defined as a horizontal angle measured clockwise from any fixed reference plane. Today, the reference plane for an azimuth in a general navigational context is typically true

north, measured as a 0° azimuth, though other angular units (grad, mil) can also be used. The azimuth cannot exceed the highest number of units in a circle – for a 360° circle; this is 359 degrees, 59 minutes, 59 seconds (359° 59’ 59”). East would have an azimuth of 90°, south 180°, and west 270°. However, there are exceptions: some navigation systems use geographic south as the reference plane. Any direction can potentially serve as the plane of reference, as long as it is clearly defined for everyone using that system.

So Azimuth means bearing and it is the angle from one direction to another. Range of Azimuth is 0°-360°.

Azimuth Ring – This is the ring formed by the top side of the Azimuth housing’s outer edge. The Azimuth ring contains rule markings of measure scale. The units of measure can be “degree”, “mil”, “quarter quadrant” or a combination of these units. The most common scale used is 0° to 360° degrees.

Azimuth Housing – This is the main body of the compass. It contains the magnetic needle and the Azimuth ring. The housing rotates within the compass base to facilitate bearing readings.

Back Bearing – The 180 degree opposite of the azimuth or bearing. Also known as back azimuth.

Back Sighting – The term used to refer to the action taken while establish a back bearing.

Base Plate – A see-through plate of an orienteering compass onto which, the compass housing is mounted.

Bearing – see Azimuth. A bearing is stated in degrees and ranges 0°-360°.

Bench Mark – A permanent object that is either natural or man-made and has a known elevation that can be used as a reference point when navigating.

Boxing The Needle is placing the red end of the magnetic needle exactly over or under the orienting arrow north marking on compass when determining a bearing. Since the marking is usually slightly larger than the magnetic needle, it appears to box the needle.

Cardinal Point / Direction – The four main directions on a compass. North, East, South, West, with angles of difference at 90°.

North - 360° or 0°;

EAST - 90°;

SOUTH - 180°;
WEST - 270°.

Clinometer – A clinometer also known as an inclinometer is an instrument for measuring angles of slope or tilt (elevation or inclination of an object with respect to gravity). Also known as a tilt meter, tilt indicator, slope meter, slope gauge, gradient meter, gradiometer, level gauge, level meter, pitch & roll indicator. It can be a device or feature on a compass to measure vertical angle, such as a slope of a hill. It can also be used as a level as well.

Contour Interval – The difference in elevation (height) between one contour line and the next. This interval is either expressed in feet or meters.

Contour Line – Found on topographical maps to indicate elevation of the land. Each contour line often comprises of an irregular closed loop that connects points of equal land elevation. The line with a darker shade of brown, typically every fifth line, is called an index contour and usually has the elevation printed on it. Elevations refer to elevation above sea level.

Curvimeter – A curvimeter, also called an opisometer, curvometer, meilograph, or map measurer, is an instrument for measuring the lengths of curved lines by hand on topological maps, charts, and graphical documents.

A simple curvimeter consists of a wheel (toothed) of known circumference on a handle. The wheel is placed in contact with the curved line to be measured and run along its length.

Declination – Magnetic Declination is basically an angle difference between true north and magnetic north that “compass needles point”. This angle varies from place to place over the world and it changes over time. Map gridlines are true north based.

Current Magnetic Declination Magnetic declinations change over time and can be found online by date. While results are accurate to 30”, you should be aware that solar storms can cause short-term disturbances in the earth’s magnetic field.

Declination Angle – The declination angle is the angle between true North and magnetic North.

Degree – A unit for measurement of plane angles. It equals to 1/360 of a complete revolution, or 1/90 of a right angle. Symbolized °. 1°=60’; 1’=60”.

Easting – Easting refers to the eastward-measured distance(or the x-coordinate), while northing refers to the northward-measured distance (or

the y-coordinate) commonly measured in meters, however imperial units (e.g., survey feet) are also used. This coordinate commonly are associated with the Universal Transverse Mercator coordinate system (UTM).

Graduation – The series of degree markings.

Index Line – Extension line of Direction-of-travel arrow that meets the Azimuth ring to ease degree reading.

Inclination – Earth magnetic field pulls down the compass needle near the poles. This pulling angle is Magnetic inclination. Compass needles must be balanced for this pull.

Latitude – The angular distance north or south of the earth's equator, measured in degrees from the equator, which has a latitude of 0°, with the poles having a latitude of 90° north and south. The distance of a degree of latitude is about 111 km; 69 miles or 60 nautical miles or knots (so 1'=1knot). Latitude and longitude are the coordinates that together identify all positions on the Earth's surface.

Longitude – Angular distance on the earth's surface, measured east or west from the prime meridian at Greenwich, England, expressed in degrees (or hours), minutes, and seconds.

Magnetic North – The direction towards which all magnetic needles point.

Magnetic North Pole – the point on the surface of Earth that lies in Northern Canada at which the planet's magnetic field points vertically downwards.

MIL – short name for a milradian. 1/1000th of a radian. Some compasses have additional mil scales as well.

Northing – Northing refers to the northward-measured distance (or the y-coordinate), while easting refers to the eastward-measured distance (or the x-coordinate) commonly measured in meters, however imperial units (e.g., survey feet) are also used. This coordinate commonly are associated with the Universal Transverse Mercator coordinate system (UTM).

Orienteering – A sport or practice in which participants find their way with the aid of a map and compass.

Orienting Arrow – Stationary, slightly wider marking, on the Azimuth housing of a compass. Orienting arrow is to be matched, "boxed" with needle when orienting or operating to establish a bearing. Sometimes used for declination correction.

Orienting Lines – Lines on the floor of the compass housing parallel to orienting arrow. Lines rotate with the housing when the dial is turned. It is used to orient a compass to a map

Protractor – An instrument for measuring and constructing angles. Useful when projecting lines across a map. A Protractor can be found as a built-in feature on a baseplate compass.

Quadrant – A circular arc of 90°; one fourth of the circumference of a circle.

Radian (Rad) – A radian is an angular measurement that is equal to the angle formed at the center of a circle by two radii cutting off an arc whose length is equal to the radius.

Topographic Map – Also referred to as Topo Map, is a 2 dimensional drawing of real, 3 dimensional terrain. Elevations are represented through a series of contour lines. Contour lines have a specific, constant elevation. The closer the contour lines are together, the steeper the actual terrain. The farther apart the contour lines, the flatter or more gradual the slope of the terrain.

True North – (TN) The direction pointing to the geographic north pole.

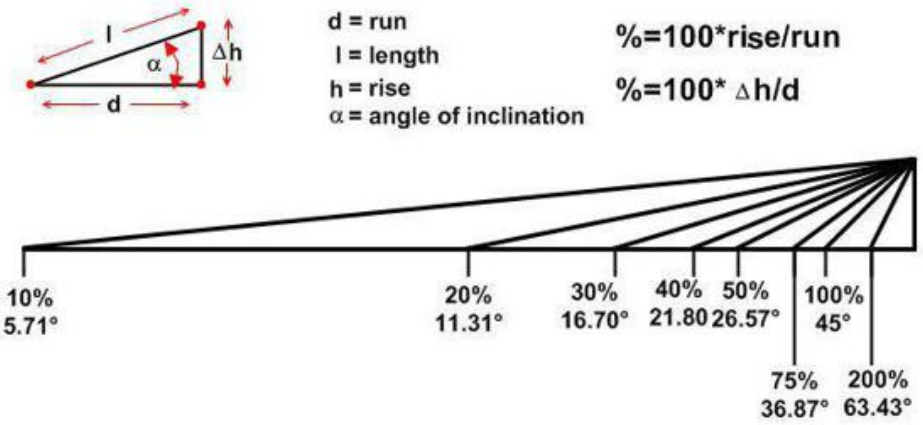
UTM – Universal Transverse Mercator. UTM uses 2 dimensional Cartesian coordinate system to give locations on the surface of the Earth. It differs from the traditional method of latitude and longitude. The system divides the Earth into sixty zones, each a 6-degree band of longitude. A position on the Earth is given by the UTM zone number and the easting and northing coordinate pair in that zone in meters.

The 32 Points of the Compass

Point	Direction	Azimuth
0	North	0° - 0'
1	N by E	11° - 15'
2	NNE	22° - 30'
3	NE by N	33° - 45'
4	NE	45° - 0'
5	NE by E	56° - 15'
6	ENE	67° - 30'
7	E by N	78° - 45'
8	East	90° - 0'
9	E by S	101° - 15'
10	ESE	112° - 30'
11	SE by E	123° - 45'
12	SE	135° - 0'
13	SE by S	146° - 15'
14	SSE	157° - 30'
15	S by E	168° - 45'
16	South	180° - 0'
17	S by W	191° - 15'
18	SSW	202° - 30'
19	SW by S	213° - 45'
20	SW	225° - 0'
21	SW by W	236° - 15'
22	WSW	247° - 30'
23	W by S	258° - 45'
24	West	270° - 0'
25	W by N	281° - 15'
26	WNW	292° - 30'
27	NW by W	303° - 45'
28	NW	315° - 0'
29	NW by N	326° - 15'
30	NNW	337° - 30'
31	N by W	348° - 45'

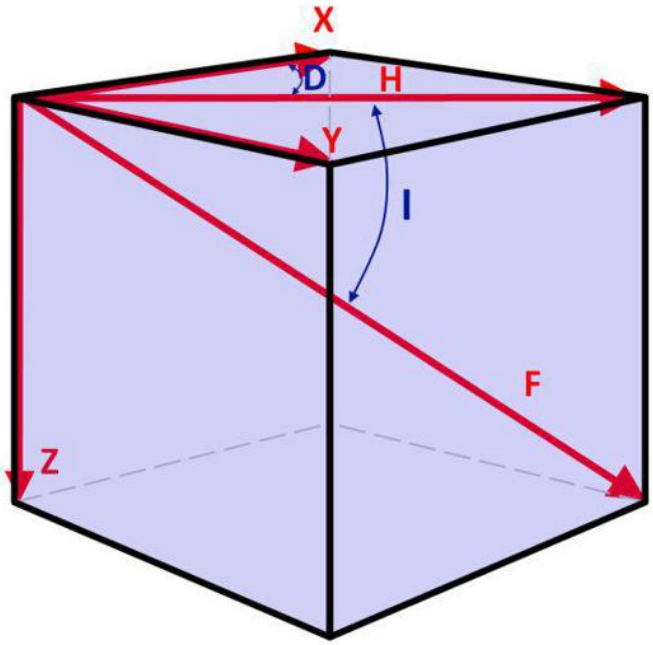
Inclination slope

The most common way to express slope is **degree angle** of inclination to the horizontal line. **Percentage** is very common as well. The formula for which is **100 * rise / run** which could also be expressed as the tangent of the angle of inclination times 100. This percentage “grade” is commonly used unit for communicating slopes in transportation such as streets, roads, highways and rail tracks.



Declination Vectors

The Earth's magnetic field is a vector, so at each point in space it has a **strength** and a **direction**.



Elements is shown in the diagram are:

F the **total intensity** of the magnetic field vector

H the **horizontal** component of the magnetic field vector

X the **north component** of the magnetic field

Y the **east component** of the magnetic field

Z the **vertical** component of the magnetic field vector; Z is *positive downward*

D magnetic **declination**; the angle between true north and the horizontal component of the field measured **eastward** from true north

I magnetic **inclination**; the angle measured from the horizontal plane to the magnetic field vector; *downward is positive*

To completely describe Earth's magnetic field vector we need three quantities.

- • three orthogonal strength components (**X, Y,** and **Z**);
- • the total field strength and two angles (**F, D, I**);
- • two strength components and an angle (**H, Z, D**)

D and **I** are measured in degrees. All other elements are measured in nanotesla (nT; 1 nT = 10^{-9} Tesla).

These elements are related through the following simple expressions.

Intensity $F=\sqrt{(X^2+Y^2+Z^2)}$

Declination $D=\tan^{-1}(Y/X)$

Inclination $I=\tan^{-1}(Z/H)$

Horizontal $H=\sqrt{(X^2+Y^2)}$

North $X=H\cos(D)$

East $Y=H\sin(D)$

Precise declinations for any location can be seen online.

Declinations Online

NOAA National Oceanic and Atmospheric Administration - http://www.ngdc.noaa.gov/geomag-web/

Natural resources Canada - http://geomag.nrcan.gc.ca/calc/mdcal-eng.php

British Geological Survey - http://www.geomag.bgs.ac.uk/data_service/models_compass/wmm_calc.html

Compass - Alex Zalk

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